DESIGN OF HIGH PERFORMANCE CLASS B PUSH PULL AMPLIFIER

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DESIGN OF HIGH PERFORMANCE CLASS B PUSH-PULL AMPLIFIER

A Thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Technology in "Electrical Engineering"

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CERTIFICATE

This is to certify that the thesis entitled "**Design of high performance class B push pull amplifier**", submitted by **Abhishek Anand (Roll. No. 109EE0249) and Avinash Minz (Roll. No. 109EE0283)** in partial fulfillment of the requirements for the award of **Bachelor of Technology** in **Electrical Engineering** during session 2012-2013 at National Institute of Technology, Rourkela. A bonafide record of research work carried out by them under my supervision and guidance.

The candidates have fulfilled all the prescribed requirements.

The thesis which is based on candidates' own work, have not submitted elsewhere for a degree/diploma.

In my opinion, the thesis is of standard required for the award of a bachelor of technology degree in Electrical Engineering.

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B.TECH (ELECTRICAL ENGINEERING)

Dedicated to

Our beloved parents

ABSTRACT

Class B push pull amplifier are the most commonly used circuit for amplification purpose due to its higher efficiency. In spite of having a very high efficiency, crossover distortion is one which severely affects the performance of Class B amplifier. It can be reduced by the use of op-amp as a negative feedback op-amp. The op-amp can also be used a buffer. The use of diode creates a dead band in the output voltage. The heating effect in the diode is reduced by the use of temperature compensation feedback resistor.

CONTENTS

Abstract i

Contents ii

List of Figures iv

CHAPTER 1

INTRODUCTION

1.1 Overview of Power Amplifiers 2

CHAPTER-2

WORKING OF CLASS B PUSH PULL AMPLIFIER

2.1 Basic principles 8

CHAPTER-3

MATHEMATICAL ANALYSIS OF CLASS B PUSH PULL AMPLIFIER 12

CHAPTER-4

PROBLEMS IN CLASS-B PUSH PULL AMPLIFIER 15

4.1 Crossover Distortion 16

4.2 How to reduce crossover distortion 16

CHAPTER-5

5.1 RESULTS AND DISCUSSIONS 20

References 23

LIST OF FIGURES

Fig. No	Name of the Figure	Page. No.
1.1	circuit diagram of class B push pull amplifier	6
1.2	output waveform of class b push pull amplifier	7
2.1	common collector class b amplifier	8
2.2	class B push pull amplifier circuit	10
2.3	Crossover distortion of amplifier	11
4.1	Crossover distortion in an amplifier	16
4.2	Circuit to counter Crossover Distortion	16
4.3	Circuit to reduce heating effect	17
4.4	Pin configuration of TL082	17
4.5	Output after reducing crossover distortion	18

CHAPTER **1**

Introduction

1.1 INTRODUCTION:

A push pull amplifier is an amplifier which has an output stage that can drive a current in either direction through the load. The output of a typical push pull amplifier consists of two identical BJTs or MOSFETs one sourcing current through the load while the other one sinking the current through the load. Push pull amplifiers are superior as compared to single ended amplifiers (using a single transistor at the output for driving the load) in terms of performance and distortion. A single ended amplifier, how well it may be designed will surely introduce some distortion due to the non-linearity of its dynamic transfer characteristics. Push pull amplifiers are mostly used in situations where low distortion, high power and higher efficiency is required. The basic operation of a push pull amplifier is as follows: The signal to be amplified is first split into two identical signals 180° out of phase. Generally the splitting is done using an input coupling transformer. The input coupling transformer is arranged such that one signal in applied to the input of one transistor and the other signal is applied to the input of the other transistor. The advantages of push pull amplifier are low distortion, cancellation of power supply ripples and absence of magnetic saturation in the coupling transformer core which results in the absence of hum while the disadvantages are the need of two identical transistors and the requirement of bulky and costly coupling transformers.

Power amplifier circuits maybe classified as A, B, AB and C for analog based designs and class D and E for switching designs based on the proportion of each input cycle, during which an amplifying device is passing current. The image of the conduction angle is found by amplifying a sinusoidal signal. If the device is always turned on, the conducting angle is 360°. If it is on for only half of each cycle, the angle is 180°. The angle of flow is closely related to the amplifier power efficiency. The various classes are introduced later, along with a more detailed discussion under their individual headings further down.

Class-B amplifiers only amplify half of the input wave cycle, hence creating a large amount of distortion, but the efficiency is greatly improved and is much better than class A. Class-B amplifiers are also favored in battery-operated devices, such as transistor radios. Class B has a maximum theoretical efficiency of $\pi/4$. (i.e. 78.5%) This is because the amplifying element is switched off altogether half the time-period, and so cannot dissipate power. A single class-B element is hardly found in practice, though it is being used for driving the loudspeaker in the early IBM Personal Computers with beeps, and it can also be used in RF power amplifier where the distortion levels are of lesser importance. However, class C is more commonly used for this.

A practical circuit using class-B elements is the push–pull stage, such as the simplified complementary pair arrangement. Quasi-Complementary or complementary devices are used for amplifying the opposite halves of the input signal, which is then recombined at the output side. This arrangement produces excellent efficiency, but has the drawback that there is a small mismatch in the cross-over region – at the "joins" between the two halves of the signal, as one of the output device has to take over supplying power exactly as the other finishes also known as crossover distortion. Improvement is done by biasing the devices so they are not completely off when they're not being used. This approach is called *class AB* operation.

In this thesis mainly we have designed a hardware model of class B amplifier by using complementary transistors, capacitors, diode and resistance of some standard specification. Finally we have calculated output voltage and efficiency by varying load resistance. We can also plot the graph of output voltage and current by using cathode ray oscilloscope.

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Amplifier circuits form the basis of most electronic systems, many of which are required to produce high power to drive some output device. Audio amplifier output power can be anything from less than 1 Watt to several hundred Watts. Radio frequency amplifiers are used in transmitters can be required to produce thousands of kilowatts of output power, and DC amplifiers are used in electronic control systems may also need high power outputs to drive motors or actuators of many different types. This module describes mostly encountered classes of power output circuits and techniques used to improve performance. There are different types of power amplifiers – class A , class B , class C , class D and class AB. This thesis mainly deals with class B power amplifiers.

In Class B amplifier, the positive and negative halves of the signal are dealt with by different parts of the circuit. The output devices continually turn on and off. Class B operation has the following characteristics. The input signal has to be a lot larger in order to drive the transistor appropriately. This is totally the opposite of Class A operation .There must be at least two output devices with this type of amp. This output stage uses two output devices so that each side amplifies each half of the waveform. Either both output devices are never allowed to be on at the same time, or the bias for each device is set so that current flow in one output device is zero when not presented with an input signal. Each output device is in on state for exactly one half of a complete signal cycle.

When a transistor in operated as class B, it clips off half the cycle. In order to avoid distortion we use two transistors in push-pull arrangement. During the positive cycle of input voltage the upper transistor conducts and the lower one cuts off. During the negative cycle the upper transistor turns off and lower one turns on. Since transistor amplifies half of input, loud speaker receives a full cycle of the amplified signal.

In order to improve the full power efficiency of thee previous Class A amplifier by reducing the wasted power in the form of heat, it is possible to design the power amplifier circuit with two transistors in its output stage producing what is commonly termed as a Class B amplifier also known as push- pull amplifier configuration.

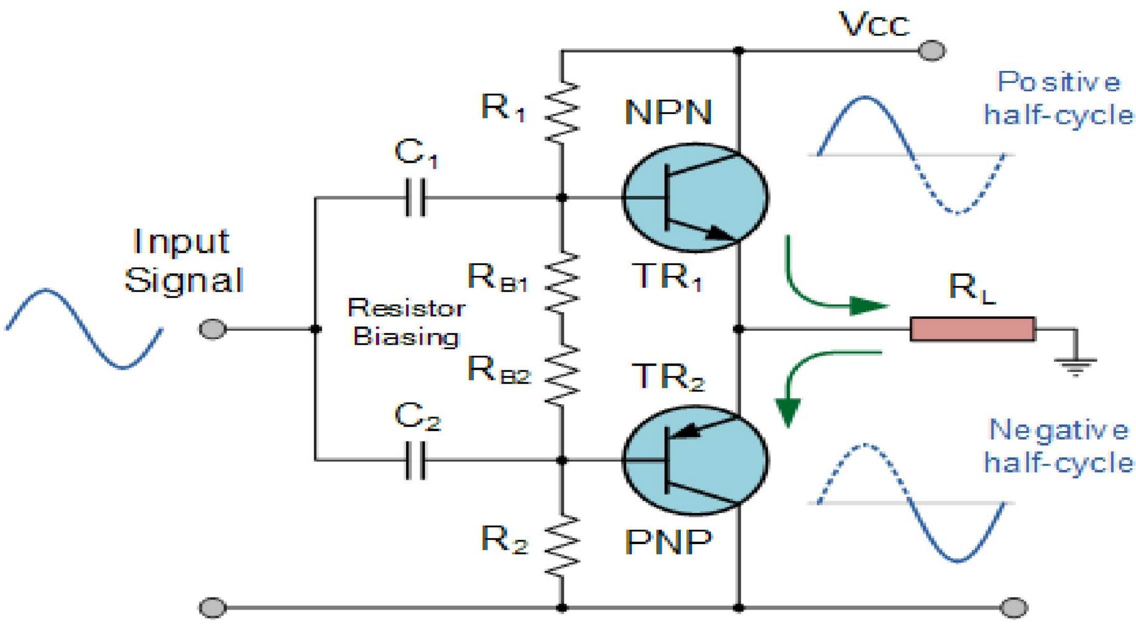

Figure 1.1: circuit diagram of a class B push pull amplifier

For hardware design of class B amplifier following are the specification we have used :

NPN Transistor - 2N2222

PNP Transistor – 2N2907

Two capacitor of 100µF each, load resistance of 8.2Ω

R1 - 68Ω , R2 - 1Ω , Vcc – 5V , RB1- 1Ω , RB2 - 68Ω , Applied input AC voltage – 20V (P-P)

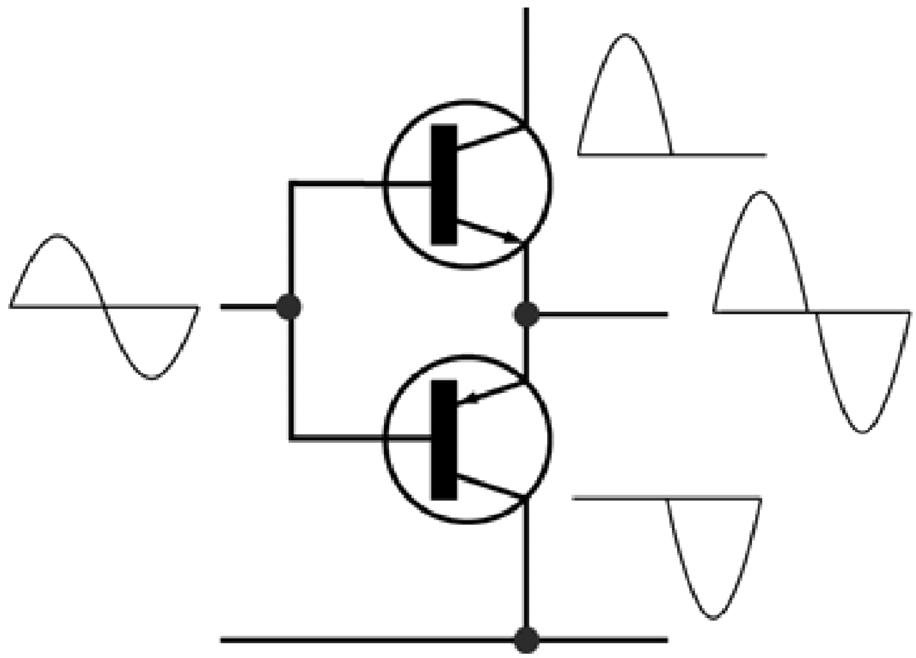

Figure 1.2 : output waveform of class b push pull amplifier

CHAPTER **2**

Working of class B push pull amplifier

2.1 BASIC PRINCIPLES:

Class-B amplifier provides an output signal varying over one-half the input signal cycle + zero phase shift. The dc bias point for class-B amplifier is therefore at 0 volt.

i.e. biased at cutoff :-

$I_{CQ} = 0$ and

$V_{ceq} = V_{ce(off)}$

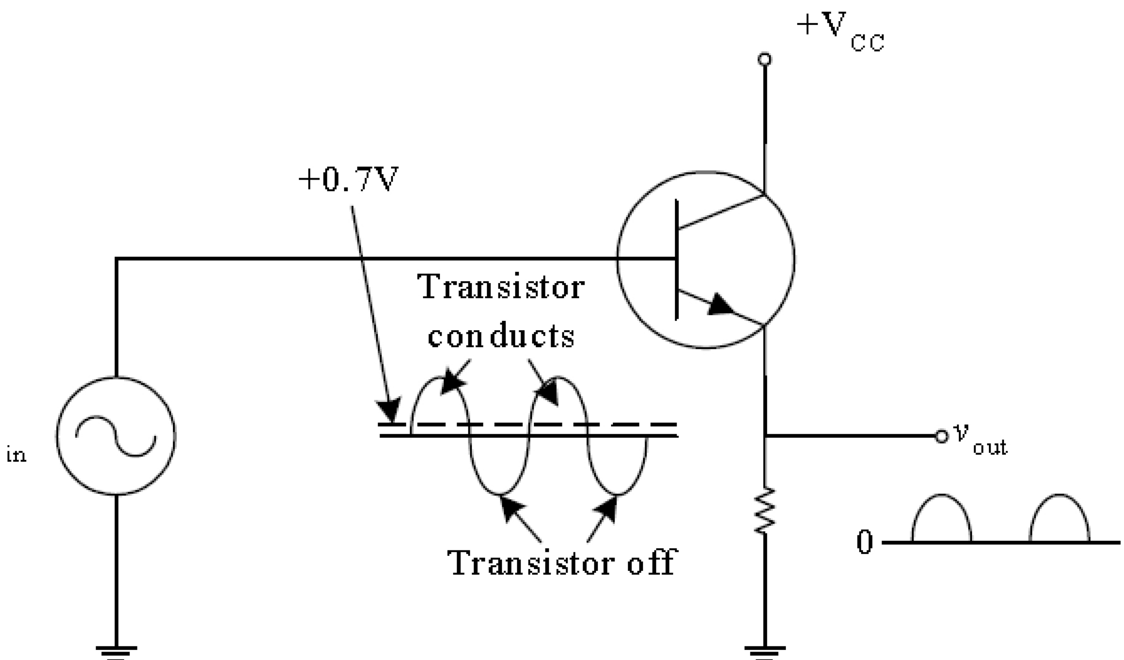

Figure 2.1: common collector class b amplifier

The advantage of a class-B amplifier is that the collector current is zero when the input signal to the amplifier is zero. Therefore the transistor dissipate no power in the quiescent condition, class-B amplifier was developed to improve on the low efficiency rating of the class-A amplifier. Obviously, the output is not a faithful reproduction of the input if only one half-cycle is present.

Therefore, a two-transistor configuration is necessary to get a sufficiently good reproduction of the input waveform. This amplifier configuration is known as push-pull emitter follower (push-pull amplifier) or complementary-symmetry amplifier. The term push-pull comes from the fact that two transistors in a class-B amplifier conduct on alternating half-cycles of the input. The combined half-cycles then produces an output for a full 360^{o} of operation.

No Input:

When the transistor is in its quiescent state (no input), both transistors are biased at cutoff.

Positive Input :-

During the positive half-cycle of the input signal, Q1 is biased above cutoff, then conduction results through the transistor *RL*. During this time, Q2 is still biased at cutoff and provide output on the positive-output half-cycle.

Negative Input :-

During the negative half-cycle of the input signal, Q1 returns to the cutoff state, and Q2 is biased above cutoff. Due to this, conduction of Q2 starts to built while Q1 remains off. provide output on the negative-output half-cycle. The combined half-cycles then provide an output for a full 360^{0} of operation.

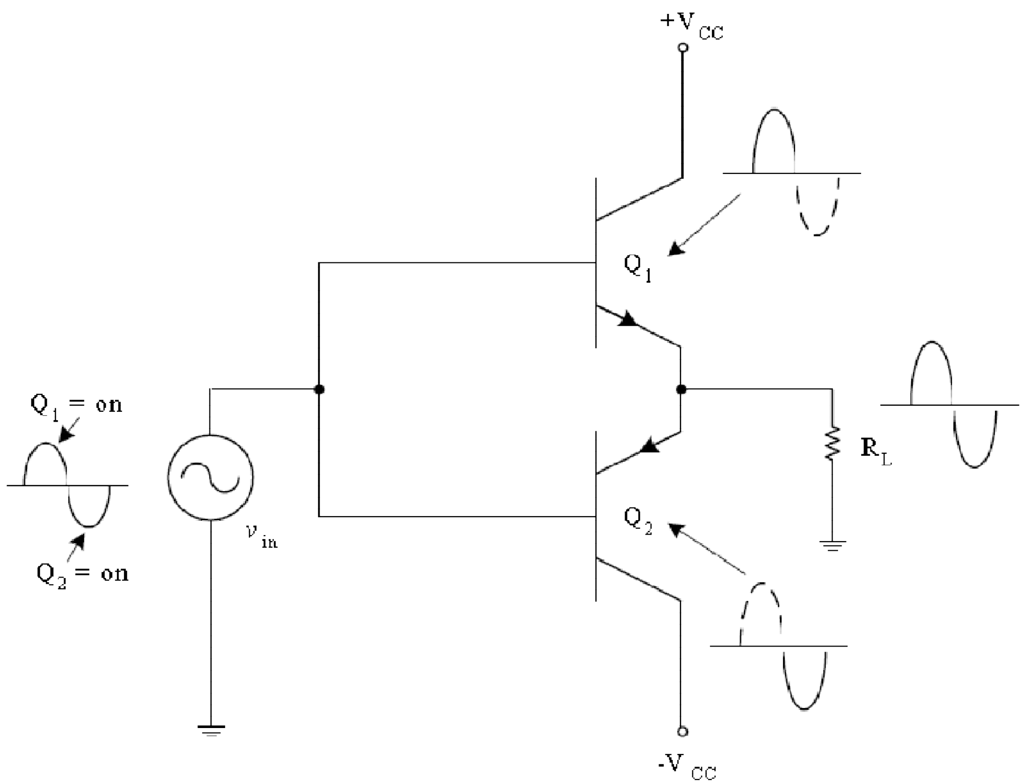

Figure 2.2: class B push pull amplifier circuit

Crossover Distortion - Among the disadvantages of a class-B amplifier is that the nonlinear cut-off region is included in the operating range. The term crossover refers to the crossing over of the signal between devices, from the upper transistor to the lower and vice-versa. This term is not related to the audio crossover a filtering circuit which divides an audio signal into frequency bands. It is most commonly seen in complementary, or "push-pull", Class-B amplifier stages.

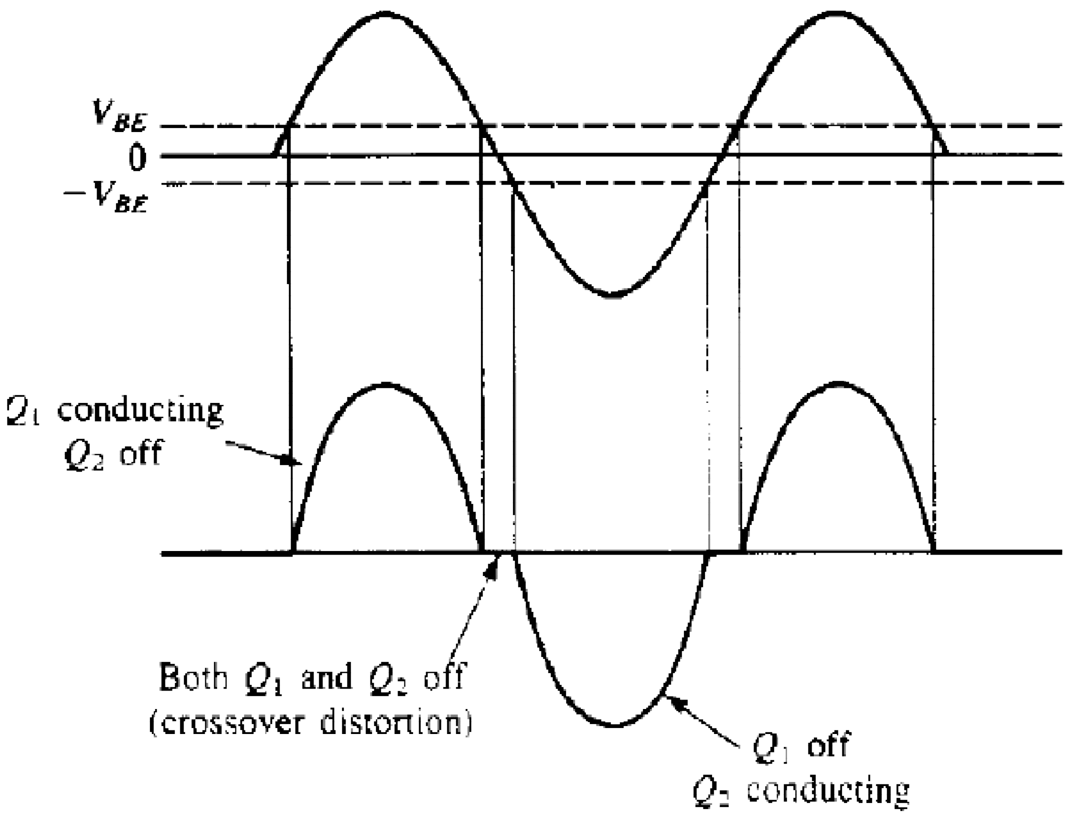

Figure 2.3: cross over distortion of amplifier

Because of the biasing, class-B amplifiers are subject to a type of distortion. When $VB = 0$, the input signal voltage must exceed *VBE* before a transistor conduct. Therefore, there is a time interval between the positive and negative alternations when neither transistor is conduction. The resulting distortion in the output waveform is quite common and is called crossover distortion. To prevent crossover distortion, both transistors are normally biased at a level that is slightly *above* cutoff. Biasing both transistors slightly above cut-off will allow the amplifier to provide a linear output that contains no distortion.

CHAPTER 3

Mathematical analysis of class B push pull amplifier

Class B operation is provided when the dc bias leaves the transistor biased just off the transistor turning on when the ac signal is applied . This is essentially no bias , and the transistor conducts current for only one half of the signal cycle. In order to obtain output for the full cycle of signal , it is necessary to use two transistors and have each conduct on opposite half cycles, the combined operation providing a complete cycle of output signal.

The power supplied to the load by an amplifier is drawn from the power supply that provides the input or dc power. The amount of this output power can be calculated using

$$P_i = Vcc * Idc \quad \ldots\ldots \quad (3.1)$$

Where, Vcc is the voltage given to collector terminal and Idc is the average or DC current.

Similarly the value of average current drawn can be expressed as

$$Idc = 2/\pi \, I(p) \quad \ldots\ldots \quad (3.2)$$

$$\text{Input dc power} = Vcc(\, 2/\pi \, I(p)) \quad \ldots\ldots \quad (3.3)$$

The power delivered to the load usually referred to as a resistance R can be calculated using any one of a number of equations. If one is uses an rms meter to measure the voltage across the load , the output power can be calculated as

$$P_o\,(ac) = V(rms)^2/R_L \quad \ldots\ldots \quad (3.4)$$

The efficiency of class B amplifier is calculated using the basic equation :

$$\% = \text{output ac power / input dc power} \quad \ldots\ldots \quad (3.5)$$

The amount of power dissipated by the output transistors is the difference between the input power delivered by the supplies and the output power delivered to the load:

$$P2Q = Pi(dc) - P_O(ac) \ldots\ldots (3.6)$$

Where, P_{2Q} is the power dissipated by the two output power transistors. The power dissipated handled by each transistor is then

$P_Q = P_{2Q}/2$ ……………………………………………………………………………………….(3.7)

For class B operation, the maximum power is delivered to the load when $V_L(P) = V_{CC}$.

Maximum output power = $V_{cc}^2/2R_L$…………………………………………………………....(3.8)

Maximum input power = $2V_{cc}^2/\pi R_L$…………………………………………………………..(3.9)

Maximum efficiency (η) = $P_0ac/ P_i dc$…………………………………………………………(3.10)

$\%\eta = (\pi*V_L)/(4*V_{cc}) *100$

$= 78.5\ \%$

CHAPTER **4**

Problems in Class B push pull amplifier

4.1 **Crossover Distortion**

Most audio amplifiers use a class B configuration, where one transistor produces power to the load during one-half of the waveform cycle and a second transistor provides power to the load for the other half of the cycle. In this scheme no transistor remains on for the entire cycle, giving rest and time for circuit to cool down. This makes a power efficient amplifier circuit but leads to a different type of nonlinearity known as crossover distortion.

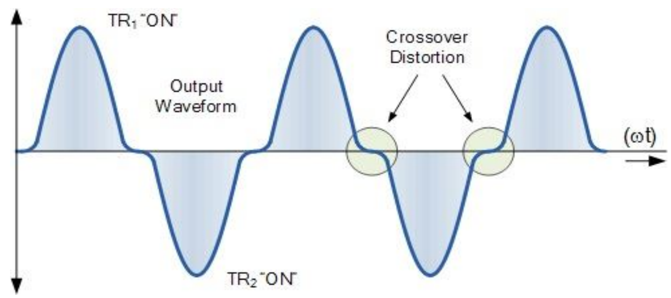

Figure 4.1: Crossover Distortion in an amplifier

4.2 How to reduce Crossover Distortion

Crossover Distortion can be countered by the use of feedback. The use of negative feedback op-amp helps it in driving through the dead zone and reduces the flattening of the waveform. The op-amp merely acts as a buffer which helps in reducing the loading of input capacitor/resistor network which has been placed in the circuit to filter out any dc bias voltage.

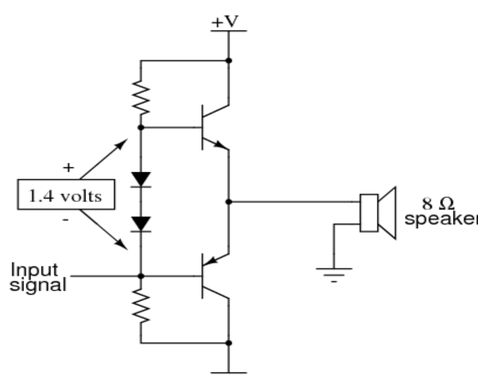

Figure 4.2: Circuit to counter crossover distortion

This solution though is not perfect, as it causes the transistors heat up from conducting power to the load. The forward voltage merely drops from 0.7 volts to 0.5 volts. The diodes continue to provide the same bias voltage of 1.4 volt. The result is that the circuit drifts into class AB operation. This results in more heat dissipation through transistors enhancing the problem of forward voltage drop. This is solved by insertion of temperature-compensation feedback resistor.

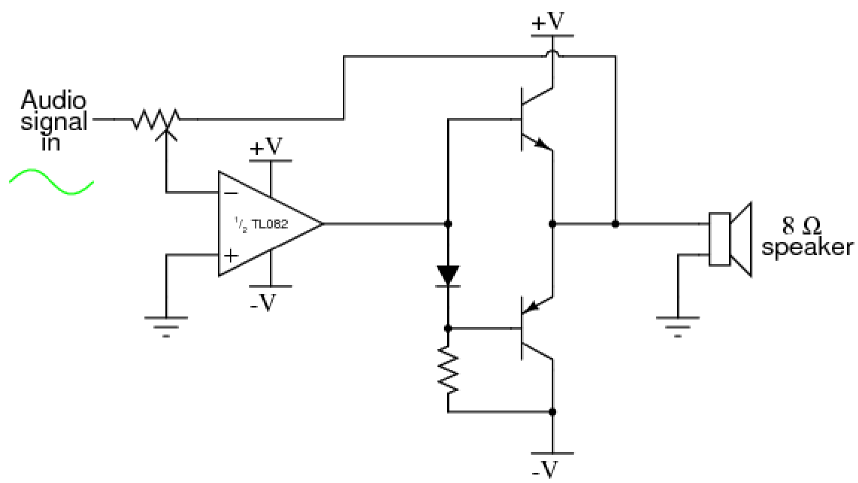

Figure 4.3: Circuit to reduce the heating effect

TL082 op-amp exhibit properties such as low input offset voltage, low input bias current, high slew rate. It is a 8 pin transistor with an op-amp in it having both inverting and non-inverting terminals. Since we need only half of the wave hence we use ½ TL082 in our circuit.

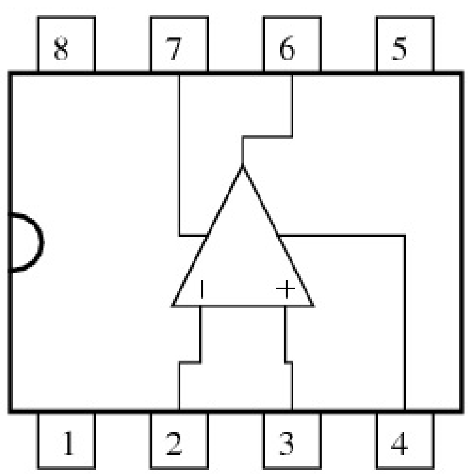

Figure 4.4 Pin configuration of TL082

Terminal 1 represents offset null

Terminal 2 represents inverting terminal

Terminal 3 represents non-inverting terminal

Terminal 4 represents negative input voltage

Terminal 5 represents offset null

Terminal 6 represents the output terminal

Terminal 7 represents the positive input voltage

Terminal 8 is left open.

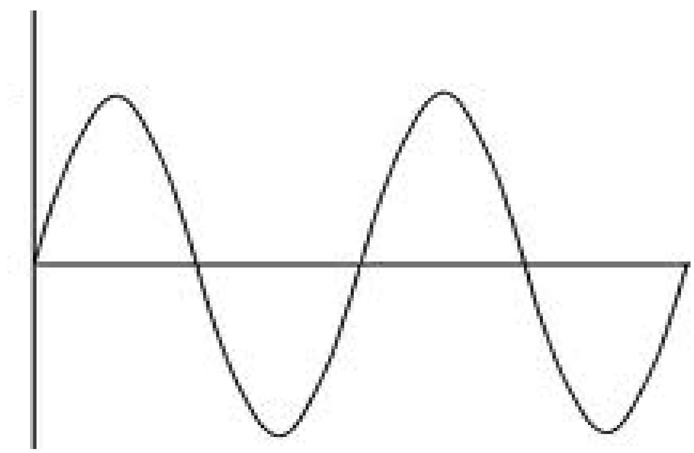

Figure 4.5 Output after reduction of crossover distortion

Chapter 5

Results and Discussion

5.1 Results

In hardware design of class b push pull amplifier , following parameters have been used :

V_i = 20v (p-p).

R_l = 8.2Ω , v_{cc} = 5v

so the peak load current can be calculated as

$I_l(p) = v_l(p)/r_l = 20/8.2 = 2.43A$.

the dc value of the current drawn from the power supply is then :

$I_{dc} = 2/\pi(i_{l(p)}) = 2/\pi\ (2.43) = 1.54$ A.

and the power delivered by the supply voltage is

$P_i(dc) = vcc * i_{dc} = 20*1.54 = 30.8$ W.

the power delivered to the load is

$P_o(ac) = v_l^2(p)/2r_l = 20^2/2*8.2 = 24.39w$.

for a resulting efficiency of

% =(P_o (ac)/ P_i(dc)) * 100 = (24.39/30.8) * 100 = 79.1%.

so , we can easily calculate load voltage , input power , output power and efficiency of class b push pull amplifier from its hardware implementation.

5.2 DISCUSSIONS:

Design of class b push pull amplifier is carried out by using different values and specification of electrical elements like resistor, capacitor, transistor etc. Two complementary transistors are used in the hardware design of above model .First of all circuit is designed according to the circuit diagram of class b push pull amplifier. Then the elements are added to counter the distortion effect .Then an input voltage of 20V peak to peak is given to the common junction of capacitors . A load is also connected at junction of common emitter across which output voltage is measured and its corresponding waveform is also drawn. Therefore we can design and analyse the hardware implementation of a high performance class b push pull amplifier.

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